Air mass characteristics observed over the western Pacific during PACE-II, III

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Abstract. During the experiments, the ozone-depleted maritime air mass dominated up to 5000 m over the equatorial region. Especially in the PACE-III (summer in the northern hemisphere), this air mass widely extended to 30°N. In the PACE-II (autumn in the northern hemisphere), the stratospheric origin air masses, which included rich ozone and low water vapor, were observed at 5000 m even in the tropics, and the air masses, which were influenced by biomass burning, were observed in the middle troposphere in the north of Australia. In the PACE-II, most of the vertical ozone gradients showed negative from the south of Philippine (7°N) to Okinawa Is. (26°N), indicating photochemical ozone productions at the tropical lower layer. On the other hand, the vertical ozone gradients increased with increasing latitudes in the both hemisphere, indicating the larger contribution from the stratosphere. In the PACE-III, most of the vertical ozone gradients showed positive in the tropics although the values were small. This suggests that during the summer, the photochemical ozone productions from anthropogenic gases in the tropics were limited due to dominated maritime air masses.

1. Introduction

The tropospheric ozone is one of the important gases for the global warming. Origins of the tropospheric ozone are thought to be intrusions from the stratosphere and photochemical productions from anthropogenic emissions of ozone precursors. The vertical and horizontal distributions of ozone result from dynamic transports and complex chemical reactions. Many aircraft observations of ozone and the precursors have been conducted in Europe, America, and Africa. Some aircraft campaigns like INSTAC (Kondo et al., 1993) and PEM-West (Hoell, et al., 1996; Browell et al., 1996) were conducted over the western Pacific, but the research areas were limited in the northern hemisphere. We performed three aircraft observations at the western Pacific from Melbourne (40°S) in Australia to Sendai (40°N) in Japan as the Pacific atmospheric chemical experiment (PACE-I, II, III). The latitudinal distributions of tropospheric ozone in the pre-PACE and PACE-I campaign were reported in Tsutsumi et al. (1996). The latitudinal ozone cross sections over the western Pacific during the PACE campaigns were showed in Tsutsumi et al. (in printing). In the PACE-II(Oct. 1994), III(Jul. 1995), the vertical distribution of the tropospheric ozone

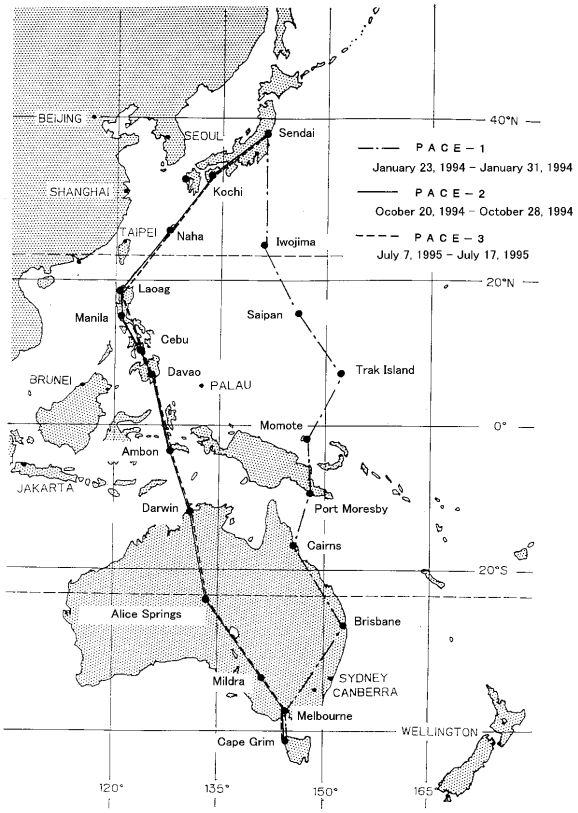

Figure 1. Flight tracks for PACE-II, III.

and aerosol number concentrations were observed when the aircraft was landing or took off. In this paper, we focus the character of air masses over the western Pacific which include ozone and aerosols.

2. Measurement methods and flight tracks

Ozone concentrations were determined using a ultra-violet absorption instrument which had been modified to get data per second except for air replacing time in the cells. The accuracy and resolution are 2 ppbv. Since water vapor fluctuations possibly affect ozone measurement in the instrument, sample air introduced from the outside of the aircraft was dehumidified to 1-4°C dew point temperature. Aerosol number concentrations (significant aerosol diameter range was 0.132-2.927μ) were determined by PMS ASASP sensor. The air temperature was measured using rosemount platinum resistance thermometer whose range is ±50°C, accuracy is 0.5°C, and resolution is 0.02°C. The dew point was measured using EG&G thermoelectric hygrometer (model 137-C3) whose range is ±50°C, accuracy is 1.1°C, and resolution is 0.02°C. But this sensor was unreliable at low temperatures (typically -15°C and colder) due to insufficient cooling current.

The aircraft using these campaigns was Fokker-27 whose air cruising speed is bout 200 kt. The flight tracks were started from Melbourne and were by ways of Mildura, Alice Springs, Darwin (Australia), Ambon(Indonesia), Davao, Cebu, Manila, Laoag (Philippine), Naha, Kochi, and Sendai (Japan) air port (see Figure 1, In the PACE-III, the flight track was not by ways of Cebu and Manila air port).

3. Results and discussions

To assess the types of air mass over the western Pacific, six air mass types were identified during the experiments, and they were categorized using the following criteria: (1) background air (BG), ozone within 30-60 ppbv; (2) natural near-surface air (NS), ozone less than 40 ppbv and clear top boundary; (3) clean maritime air (CM), ozone less than 20 ppbv and vague top boundary; (4) stratospheric air (ST), ozone more than 50 ppbv, water vapor less than 2 g/kg, aerosols less than 10^7 m^{-3} and clear bottom boundary; (5) polluted near-surface air (PS), ozone more than 50 ppbv, water vapor more than 10 g/kg, aerosols more than 10^7 m^{-3} and clear boundaries; (6) biomass burning air

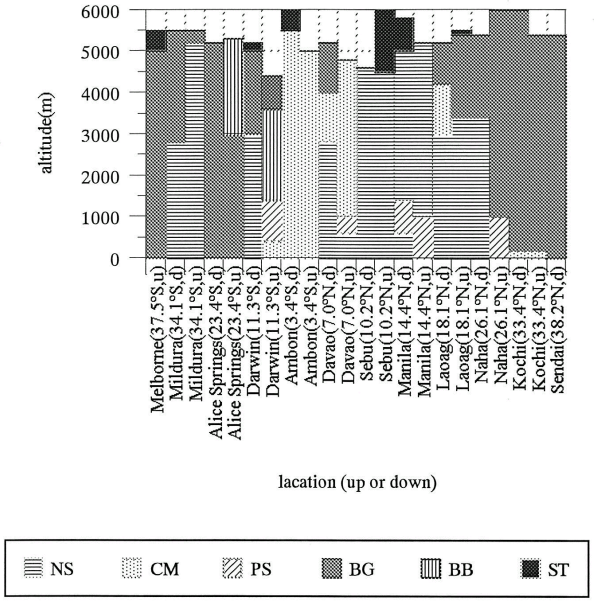

Figure 2. Air mass types over the western Pacific Ocean during PACE-II. The air masses were categorized as background air (BG), natural near-surface air (NS), Clean maritime air (CM), stratospheric air (ST), polluted near-surface air (PS), biomass burning air (BB). Notations "(u)" and "(d)" mean ascending flight and descending flight respectively.

(BB), ozone more than 50 ppbv, water vapor less than 5 g/kg and aerosols more than 10^8 m^{-3}. The biomass burning air (BB) is confirmed by detection of potassium in the collected aerosol particles, but shows relatively low water vapor concentration. Some portion of water vapor may have been absorbed by large particles and removed by

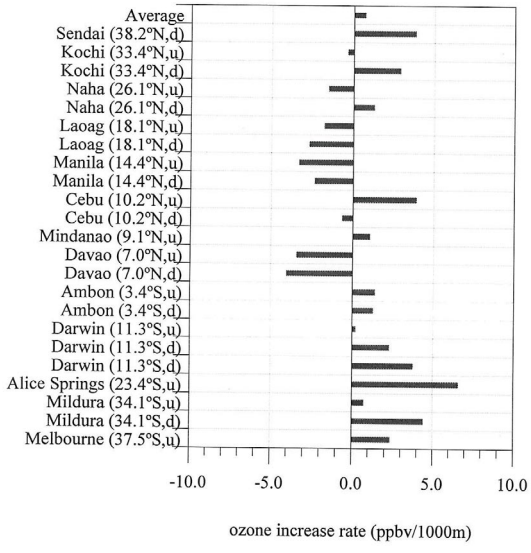

Figure 3. Vertical ozone increasing rates (ppbv/1000m) over the western Pacific Ocean during PACE-II.

particles sedimentation.

In the Figure 2, as a whole, the natural near-surface air (NS) and the background air (BG) dominated over the western Pacific Ocean during the PACE-II which was conducted in the autumn in the northern hemisphere. Vital convection, which was result in strong radiation in continental or the tropical islands, lifted up the natural near-surface air (NS) to 5000 m level in Australian inland and Philippine. The clean maritime air (CM), which may be brought about by active cumulous convection, was located at 5000 m level in the equatorial region. In the upper level (>5000m), the stratospheric air (ST) was observed even in the tropics. The biomass burning air (BB) was located at the north of Australia. The origin was identified by detection of potassium in the collected aerosol particles (Okada et al., this issue). Since this air mass was observed in the 500 km range along the flight track, the air mass was not influenced by local biomass burning which occurred just below the flight track, but is thought to have received overall influences of biomass burning in the northwestern part of Australia. The backward trajectory analysis also shows that this air mass stayed for longer than 5 days in the northwestern part of Australia (Tsutsumi et al.). The polluted

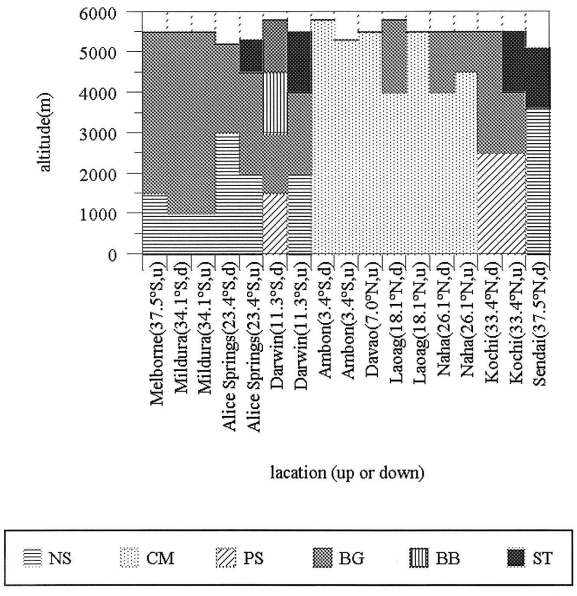

Figure 4. Air mass types over the western Pacific Ocean during PACE-III. The air masses were categorized as background air (BG), natural near-surface air (NS), Clean maritime air (CM), stratospheric air (ST), polluted near-surface air (PS), biomass burning air (BB). Notations "(u)" and "(d)" mean ascending flight and descending flight respectively.

near-surface air (PS) existed in the some tropical boundary layers (Manila, Davao, Darwin). This result reflects developments of motorization in developing countries as pointed out by Oak (1986). In the Figure 3, most of the vertical ozone increase rates, which were calculated from least square method, show negative between Davao (7°N) and Naha (26°N), indicating photochemical ozone productions in the tropical boundary layers. On the other hand, the vertical ozone increase rate increased with increasing latitudes in the both hemispheres. This means that the stratospheric contribution to the middle troposphere increased with increasing latitudes.

In the PACE-III which was conducted in the summer northern hemisphere, the clean maritime air (CM) dominated between Ambon (3°S) and Naha (26°N), although the polluted near-surface air (PS) and biomass burning air (BB) were observed at the middle or low troposphere in the north of Australia and the south of Japan (Figure 4). The clean maritime air (CM) distribution is consistent with one of the major contribution of clear maritime air mass to the southwestern Pacific Ocean as pointed out by Browell et al. (1996). Most

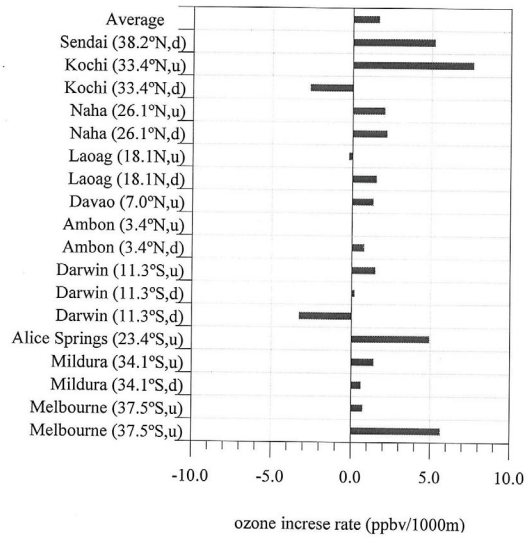

Figure 5. Vertical ozone increasing rates (ppbv/1000m) over the western Pacific Ocean during PACE-III.

of the vertical ozone increase rates show positive while the values were small (Figure 5). The dominated summer anticyclone, which includes ozone-depleted maritime air masses, overspreads the southwestern Pacific Ocean. Since water vapor and strong ultraviolet radiation lead to photo-chemical ozone destruction (Liu et al., 1983; Smit et al., 1989; Ridley et al., 1992), photochemical

ozone productions by anthropogenic emissions may be limited in the moist maritime air masses. The stratospheric air (ST) was observed at the northern middle latitudes and southern middle and low latitudes. A tropopause folding occurred at 40°N brought about high ozone concentrations in the middle troposphere over Japan (Tsutsumi et al.). The tropopause foldings observed during summer over Japan are limited.

4. Conclusion

Two aircraft observations were conducted from the southern hemisphere to the northern hemisphere over the western Pacific Ocean in the summer and autumn in the northern hemisphere. The air masses over the western Pacific have different kinds of distribution from seasons. In the summer northern hemisphere case, the maritime air mass originated from the tropics extended to the middle latitudes, bringing about low ozone concentrations and low vertical ozone increase rates. In the autumn northern hemisphere case, the air masses influenced by the earth's surface lifted up to the middle troposphere over Philippine in place of summer maritime air masses. In the both cases, the air masses influenced by biomass burning were observed at the middle troposphere in Australia.

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Figure 1 Flight tracks for PACE-II, III.

Figure 2 Air mass types over the western Pacific Ocean during PACE-II. The air masses were categorized as background air (BG), natural near-surface air (NS), Clean maritime air (CM), stratospheric air (ST), polluted near-surface air (PS), biomass burning air (BB). Notations "(u)" and "(d)" mean ascending flight and descending flight respectively.

Figure 3 Vertical ozone increasing rates (ppbv/1000m) over the western Pacific Ocean during PACE-II.

Figure 4 Air mass types over the western Pacific Ocean during PACE-III. The air masses were categorized as background air (BG), natural near-surface air (NS), Clean maritime air (CM), stratospheric air (ST), polluted near-surface air (PS), biomass burning air (BB). Notations "(u)" and "(d)" mean ascending flight and descending flight respectively.

Figure 5 Vertical ozone increasing rates (ppbv/1000m) over the western Pacific Ocean during PACE-II.